Summary of the Interagency Crab Research Meeting held December 16-18, 2003

by

Peter G. van Tamelen and Doug Woodby

REGIONAL INFORMATION REPORT[1] NO. 5J04-04

Alaska Department of Fish and Game
Division of Commercial Fisheries
P.O. Box 25526
Juneau, Alaska 99802-5526

January 2004

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AUTHORS

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The authors thank the presenters for providing us with electronic copies of their slide presentations, allowing us to faithfully summarize the material presented. The authors of this report accept responsibility for errors in interpretation.

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PURPOSE

This report summarizes the tenth annual interagency crab research meeting, held December 16-18 in Anchorage at the Hotel Captain Cook. This meeting continued the tradition of providing an informal opportunity for researchers from each of the active crab research centers to present their latest work on Alaskan crab species among peers. The meeting closed with a half-day session devoted to overfishing definitions, biological reference points, and related issues.

PARTICIPANTS

The 2003 meeting was well attended with over 50 participants representing the Alaska Department of Fish and Game (ADF&G), the National Marine Fisheries Service (NMFS), the North Pacific Fishery Management Council (NPFMC), the School of Fisheries and Ocean Sciences of the University of Alaska Fairbanks (UAF), the United States Geological Service (USGS), and the Department of Fisheries and Oceans, Canada (DFO). A list of participants and contact information is included in Appendix 1.

PRELIMINARIES

The meeting was jointly chaired by Doug Woodby and Rich Marasco, with audio-visual operations managed by Peter van Tamelen. Following staff introductions and welcoming remarks, the draft agenda (Appendix 2) was adopted without change, except that several scheduled presentations were cancelled due to illness or other factors. Those presentations were by Frank Morado (NMFS), Bob Otto (NMFS), Lisa Seeb (ADF&G), and André Punt (University of Washington).

SUMMARIES OF PRESENTATIONS

The order of presentations follows the agenda (Appendix 1), which was organized roughly by agency and then by region. Only the presenting author is listed, unless otherwise requested by the authors.

NMFS–AFSC (Seattle and Kodiak))

P. Jensen: Bitter crab disease research

The hypothesis is that bitter crab syndrome is an important factor contributing to the lack of recovery of Bering Sea *Chionoecetes bairdi* (bairdi) and the decline of C. *opilio* (opilio). The disease is due to infection by *Hematodimium*, a parasitic dinoflagellate. Prevalance is highest among small crabs, averaging about 45-50% for bairdi (carapace width (CW) = 20 mm) and 8% to 18% for opilio (CW 20–40mm). Given that the disease

is fatal, this implies significant mortality of small crab. We still know little about the life history of this disease and nothing about how it is transmitted. Current detection methods include gross visual inspection of the crab, which can only detect infection at later stages, and of blood smears. Examining blood smears allows earlier detection, but requires considerable training, is time-consuming, and is not very sensitive. The purpose of this research is to develop a polymerase chain reaction (PCR) based technique that can detect infection at very low levels, possibly a single cell per sampled blood volume, and that can be used to identify strains or species of *Hematodinium*. If successful, this technique also may prove useful in identifying modes of transmission.

K. Swiney: Egg development in *C. Bairdi*

Research objectives were to 1) determine when primiparous and multiparous females extrude eggs, 2) compare egg development between the 2 groups, and 3) confirm timing of egg hatching for both groups. Preliminary findings as of November 2003 were that:

- Primiparous females extrude eggs many months earlier than multiparous
- Primiparous eggs are smaller than multiparous eggs until approximately November
- Primiparous and multiparous eggs remain at stage 4 through August
- After August, primiparous and multiparous both develop quickly and appear to be synchronized.

For the duration of this study, both groups of females will to be sampled monthly until egg hatching, at which point, timing for primiparous and multiparous egg hatching can be verified.

K. Swiney: Dungeness crab size at maturity

Size at maturity of Dungeness crab in Alaska is largely unknown. Commercial size limit in Alaska is based upon studies in Washington (Cleaver 1949) and British Columbia (Butler 1960). Our goal is to determine size at maturity to evaluate appropriate legal size limits. For this study, physiological maturity is the size at which male crabs produce spermatophores, whereas functional maturity is defined as the size at which males and females are able to mate and extrude eggs. Preliminary results for physiological maturity, based upon relatively small sample sizes, suggest 100% of males are mature at >71 mm CW, 50% at 61–70 mm CW, and 0% at 51–60 mm CW. Functional maturity was tested with 43 lab mating experiments but results are too preliminary to draw any conclusions at this time. Another year of mating studies is planned which should help to more accurately determine the size of functional and physiological maturity. Plans also include genetic testing for embryo paternity.

ADF&G—Southeast and Central Regions

G. Bishop: PIT tagging of Tanner crab

This project investigated a combination of Passive integrated transponder (PIT) tags and fluorescent dye marking with a goal of developing a retained and detectable tag for

Tanner crabs that does not substantially increase mortality. PIT tags were injected into the crab body hemocoel just to the right of center along the posterior margin. Dye was injected into the right chela. PIT tag plus dye treatments suffered higher mortality than either the control or the single tagging treatments (PIT tags or dye), and single tagging method treatments were not significantly different than the control. It appeared that molting may have been delayed or absent in PIT tagged crabs, but no effect on molt increment was detected. All PIT tags were retained. There was evidence that the super glue used to seal the tag injection site may have caused tissue damage. Twenty PIT tagged crabs were seeded into 3 commercial totes in a processing plant. Eighteen (90%) of the crabs were detected by biologists as crabs were removed from the totes for processing. Visibility of the phototonic dye marks faded quickly even though dye was retained in the muscle through the molt. Proposed changes if done again: won't use dye, won't use superglue, but will use real cannery workers instead of biologists to estimate detection rates.

J. Rumble: Dungeness crab survey in Southeast Alaska

One of the main objectives of the survey was to develop a pre-season index of abundance. Other objectives included estimating timing of molting, mating, and egg extrusion; estimating molt increment and frequency for males, and estimating natural mortality. Catch per pot was not fully indicative of abundance because some males were in soft shell condition and not readily captured in certain years. Male molting occurred in early summer (June), and the percent of soft shell males was highly variable between areas and years. Females molt later in the summer (Aug./Sept.). Evidence was provided that females do not extrude eggs every year, in support of prior work by Swiney and Shirley. Tag return rate was 20% of 7,767 males tagged. Growth increment is estimated at 30 mm for crabs 130–170mm CW, which is similar to prior tagging derived work in southeast Alaska (estimates of 26 and 30 mm during two periods in the 1960s by Lehman and Osborne).

B. Bechtol: Central region crabs

All crabbing is currently closed in Cook Inlet and Prince William Sound (PWS). Stocks are all low but there are recent pulses of pre-recruit Tanner crabs in lower Cook Inlet and possibly PWS. In PWS, smaller crabs do not show up later as larger crabs. They are cutting back on their Dungeness survey but starting to implement a golden king crab survey in PWS and plan to set about 250 pots in March.

P. van Tamelen: Electronic data capture for crab surveys

The objectives of this study were to compare the costs and time used for electronic data capture (EDC) relative to handwritten data capture methods used in crab surveys. EDC involved 1 person using digital calipers and a handheld computer with specially developed software for crab surveys. EDC has fewer opportunities for human induced error, was about 3 times faster to get data from the crab to the computer, and had faster sampling times as well as mostly eliminating data entry. Hence, there is less time spent collecting and entering data, allowing for increased sample sizes and reduced costs for

samplers. Cost savings are minor relative to entire survey due to high vessel costs. Improvements include using a large touch screen, a more user-friendly interface, and wireless networking with the shipboard computer used for data storage.

DFO—Canada

B. Bornhold: Overview of crab fisheries in BC, Canada

Harvests are mostly Dungeness crab (90%) with some red and golden king crab, Tanner crab, and some others. Dungeness landings are worth about $26 million (CAN), with the largest annual catches coming from the Queen Charlotte area (Area A). The size limit is lower than for Washington State, making for some difficult enforcement issues when crab is exported to Washington. There is little enforcement of regulations and subsequently little compliance. Violations involve fish slips (tickets), log books, pot limits, biodegradable twine (rot cord) and more. The result is that management does not get adequate information. In response, DFO prepared a discussion document to come up with methods to change the current situation. They proposed some solutions and the fishers are currently discussion the various options. In their biggest production area (Area A), they now have a good relationship with the fishers and all fishers have the electronic monitoring equipment in place (with onboard video cameras, pot tag detection and recording, and hydraulic gear monitors). They are developing programs with the Area A fishers to examine soft shell crabs and recover lost/abandoned pots. They are just developing a deep water Tanner crab fishery (*C. tanneri*) but there is not much interest yet. Other research they are doing include soak time studies, catchability of plastic traps, evaluation of intensive Dungeness fishery, and multispecies trawl surveys. Research is mostly industry funded, so the goals are primarily to maximize catch and minimize losses.

ADF&G—Westward Region

R. Burt: Crab observer database project

The crab observer database has expanded greatly since the observer program started in 1988. Four types of data are collected: biological data, gear and location data, incidental species data, and confidential skipper interviews. The database has evolved from spreadsheet files to Rbase and now to a client/server relational database. They are still working to verify the last of the data, to finalize the structure of the database, and to integrate observer tracking and management databases.

M. Schwenzfeier: Crab observer coral bycatch recording project

As of 1999, crab observers began collecting specimens of coral bycatch from the Bering Sea/Aleutian Island (BSAI) crab fisheries for identification purposes. A protocol was established for coral bycatch data collection in 2002. Bruce Wing and David Barnard led a coral identification workshop for observer trainers and ADF&G staff in March, 2003.

Observers are now trained in coral identification. Most corals are encountered during the Aleutian Islands golden king crab fishery where coral bycatch is found in many of the pots. Corals that cannot be identified are preserved and submitted for later identification. An updated draft of the illustrated Alaskan corals identification key has been submitted to NMFS for publication.

K. Granath: Aleutian Island golden king crab survey

A triennial pot survey for golden king crab in the eastern Aleutian Islands (near Amutka and Yunashka Is.) is conducted to get relative abundance of the population, to tag crabs, and to assess movement and growth. Survey years are 1996, 1999, and 2003. Tags were applied to 100% of legal and prerecruit 1 males, 50% of smaller (<121 mm CW) sublegal males, and 25% of females. Average catch rate is 22 crabs per pot, with 7,760 crabs tagged of 19,645 caught in the past 3 surveys. Numbers caught in all categories, especially females and sublegal males show declines over the period 1996–2003. The survey coverage has expanded slightly to include peripheral areas. A diverse array of bycatch is recorded, including various other crabs, groundfish, corals and sponges. Small golden king crabs are often found inside sponges. *(This presentation was made by K. Granath for L. Watson who could not attend due to illness).*

S. Gish: Pribilof Island red and blue king crab survey

The goal of this study was to document the distribution and relative abundance of red and blue king crabs in the Pribilof Islands area and to determine if it is possible to have a red king crab fishery with little or no bycatch of blue king crabs. The impetus for this research is 1) the low stock condition of Pribilof blue king crab, which prompted a closure of king crab fishing in the area and triggered development of a rebuilding plan for blue king crab, and 2) industry and local interests in harvesting red king crab. Catch rates for legal crab in the 696 pots sampled were very low for both species: 0.57/pot for red and 0.07/pot for blue. Most of the crabs of both species were found on the northeast sides of the islands with substantial overlap. The conclusion is that it is not possible to have a red king crab fishery without impacting the blue king crabs. Additional work included mapping benthic habitats and sampling stomach contents of crabs.

D. Urban: Size at maturity for Tanner crabs in the northeast Kodiak Island area

This study investigated geographic differences in size at maturity for male Tanner crabs on the northeast side of Kodiak Island. An image analysis system was used to measure crabs. A large range (about 22 mm) in size at maturity was observed in Marmot Bay with an overall average of 120 mm CW. In general, smaller mature crabs were found at the outer stations while larger mature crabs were found at inner stations. This suggests there may be two separate stocks but the difference could also be caused by differential growth rates. Also examined stomach contents of Cod and found that Tanner crabs are an important food source. Qualitative size frequency analysis of ingested Tanner crabs suggests differing molt increments for the smaller crab (10–40 mm CW) between the inner and outer populations.

S. Byersdorfer: King crab field manual

This was an update on progress towards production of a manual similar to the *Chionoecetes* field manual published by Sea Grant in 1999. The purpose of the king crab manual is to increase consistency among data collectors, disseminate information, and encourage the correct use of terms. The manual will have sections on taxonomy, life history, distribution, external and internal anatomy, morphometrics, clutch fullness, shell aging, and diseases and parasites. Funding to publish the manual on waterproof paper is being sought.

ADF&G—Headquarters

P. van Tamelen: Using thermal modeling to reduce handling mortality in snow crabs

The objectives were 1) to identify all heat exchange mechanisms (physics and engineering), 2) to test the predictions of cooling effects on live crabs, 3) to determine what constitutes severe weather for crabs, and 4) to evaluate effectiveness of delaying the season or reducing fishing hours to reduce chill related handling mortality. The relevance of this work is that about 1/3 of all snow crab caught in the commercial fishery are discarded due to size, and this is done during a winter fishery in cold conditions with potential chilling effects on crab survival. Heat exchange was modeled with 5 components: convection, evaporation, radiation, solar, and sky radiation, and predictions were made for the following crab parts: body, chela, 1^{st}, 2^{nd}, 3^{rd}, and 4^{th} walking legs, and eyes. Predicted temperatures were generally within a degree of measured temperatures over 5 minute time spans. Weather conditions determined to be most severe for crabs are cold, clear nights. Based on weather records, delaying the season start date would reduce handling mortality only if delayed until March. Limiting fishing hours to daytime only would result in a larger and more consistent reduction in handling mortality than delaying the season.

UAF

T. Shirley: Temperature effects on energetics of snow crabs

The wet and dry weights and energy contents of organs (somatic muscle tissue, hepatopancreas, gonads, gills, heart, carapace, and digestive tract) were compared for 78 ovigerous female snow crabs cultured for one year at various temperatures (–1, 0, 1, 3, and 6°C) to simulate possible bottom temperatures in the Bering Sea. Digestive glands had higher energy content than gonads at all temperatures, but differences between temperature treatments did not appear to be biologically significant. Further results are pending completion. Other projects include 1) sea otter predation and the bathymetric distribution of Dungeness crab near Glacier Bay, Alaska (by K. Scheding), and 2) golden king crab movement and habitat selection (by Z. Hoyt).

B. Bluhm and T. Shirley: Lipofuscin ageing of snow crab

This was an update on progress with a multi-year project to evaluate the use of lipofuscin as a predictor of snow crab age. Lipofuscin is an autoflourescent metabolic waste product that accumulates through time in nervous tissue. There is a good relationship between crab size and lipofuscin concentration at small sizes. AIn mature crabs, the concentration shows a wide spread as crabs age but do not grow in size. Old shell, mature crabs tend to have higher lipofuscin concentrations than new shell mature crabs, but there is considerable overlap between the two groups. Age was estimated using modal analysis of lipofuscin concentration peaks, similar to methods used for size frequency distributions. Based on this method, maximum ages were estimated up to 15 years for a sample of 131 males and up to 7 years for a sample of 89 females. Next steps are to validate ages, increase sample sizes for better resolution of pigment peaks, try the method on other crabs, and examine temperature effects.

W. Park: Larval migration and seasonal timing of 4 *Cancer* spp. in Southeast Alaska

This project examined larvae of *C. magister*, *C. oregonensis*, *C. productus*, and *C. gracilis*, with monthly bongo net sampling of crab larvae within 20m of the surface in Icy Strait at 3 hour intervals from June to September. *Cancer oregonensis* larvae were most abundant (4233), followed by *C. magister* (209) and *C. productus* (39). Data on *Cancer gracilis* was adopted from inner Glacier Bay. Larval density peaked in June while no larvae were found in September. *C. magister* larvae had a crepuscular migration. *C. oregonensis* larvae had a strong diel vertical migration (DVM) in June. Earlier stages of *C. oregonensis* were relatively more abundant during daytime, while later stages were more abundant at night. In July, later larval stages of *C. oregonensis* were distributed at the surface all day with a peak at 2200 hours. Larvae of *C. productus* first occurred in July and peaked in August. *C. productus* had DVM but many were at the surface diurnally. Larval seasonality varied among species. *C. magister* and *C. oregonensis* larvae with relatively larger body sizes co-occurred seasonally, followed by the phytoplankton bloom; however, *C. productus* and *C. gracilis* with a relatively smaller body size appeared two months later, either followed by shorter secondary phytoplankton blooms or occurred during non-bloom periods in southeastern Alaska.

J. Webb: Effect of temperature on snow crab zoeae

This project is one aspect of the Reproductive Biology of Snow Crab (REBOS) program. Ovigerous females were held at temperatures of –1, 0, 1, 3, and 6°C. Quantities measured were time to hatch, Zoeal energy content, zoeal weight, and zoeal morphology in larvae raised at different temperatures. Time to hatch was greater in colder temperatures: mean incubation period increased 108 days (31%) with decreasing temperature (6 to –1 °C). No or minimal effects were found of temperature on zoeal weight and energy content. Little difference was found in width or rostrodorsal length among zoea raised at different temperatures. Posterior lateral spine length increased with temperatures, and this is noteworthy because this trait is used to distinguish *C. opilio* and *C. bairdi*.

S. Tamone: Terminal molt in snow crabs

The objective of this project was to determine if it is physiologically possible for male snow crabs to molt after their molt to maturity; i.e., is the molt to maturity a terminal molt? The experimental method was to remove eyestalks, which contain a sinus gland that secretes a molt inhibiting hormone. Hence, eyestalk ablation stimulates ecdysteroid secretion in crabs that are physiologically capable of molting. This treatment was applied to 15 each of 30 mature males, 30 immature males, and 30 mature females; the remainder served as controls. Hormone levels were measured in crab hemolymph periodically after eyestalk ablation. Typically, ecdysteroids increase before the molt. No differences in hormonal response between controls and treatments were seen in mature males and females, but ecdysteroid hormones increased dramatically in immature males with ablated eyestalks compared to controls. Also, there was no limb regeneration or setogenesis in mature crabs, which would be expected if they were to molt. The conclusion is that snow crabs undergo a terminal molt.

J. Mitchell: Effect of temperature on reproductive hormones in snow crabs

The hypothesis tested was that ovarian maturation is correlated with temperature. The hormone involved in ovarian maturation, methyl farnesoate, is expected to increase during ovarian maturation and vitellogenesis, and decrease upon egg extrusion. Snow crab females were kept at –1, 0, 1, and 3øC, and hemolymph was sampled in order to analyze methyl farnesoate levels using high performance liquid chromatography. Work is in progress and results are preliminary, but the early indication is that crabs held at warmer temperatures extrude eggs earlier than crabs held at cooler temperatures.

USGS

J. Taggart: Dramatic increase in size of Dungeness crabs following closure of commercial fishing

This work is part of the ongoing multi-agency Dungeness study (MADS) project in Glacier Bay and nearby areas. Prior to commercial fishery closure in 1998, 3 controls (fished) and 3 treatments (closed waters) were set up for monitoring crab populations. Due to more extensive closures than anticipated, only one control site (Gustavus flats) remained after closure. After closure, large males increased in size and abundance in the closed areas, but females did not increase in size or abundance, and sub-legal males did not increase in abundance. Before closure, male catch rate (crabs/pot) was a decreasing function of crab size, whereas after closure, catch rate increased with crab size. Sea otters are not thought to be a factor in this experiment, as they mostly occur outside of the study sites.

T. Shirley, J. Taggart, and J. Mondragon: Patterns of limb loss in Dungeness crabs before and after closure of a commercial fishery in Glacier Bay, AK

Limb loss is potentially caused by agonistic interactions, predation, and commercial fishing. Pattern of missing appendages is similar for all Dungeness crabs and for right

and left sides: chelipeds are most often lost, followed by the last walking leg, and then the inner legs. Crabs usually lose only 1 limb. Females lose more limbs than small males, which have more missing than large males. This ranking is consistent over 6 bays and 11 years. The incidence of missing appendages varying greatly between years (2 times or more) and appears cyclical.

Conclusions: Appendage loss was higher when crab abundance was lower. Therefore, limb loss was probably not caused by agonistic interactions. Incidence did not differ between fished and unfished bays, or change before and after fishing closure. Therefore, limb loss is not primarily caused by commercial fishing. This leaves predation as the probable cause, and there are many crab predators in the areas (e.g., halibut, sea and river otters, octopus) that may be responsible. Also, there are not enough crabs with regenerating limbs to explain those without limbs, suggesting limb loss results in death. Large males had highest mortality, as measured by incidence of regenerating appendages. Hence, limb loss has large effects on reproductive potential, particularly on largest and most fecund individuals. Limb loss affects survival, molting probability, and probably mate selection.

S. Elmejjati: Physiological responses of Tanner crabs to physical stressors associated with Alaskan crab fisheries

The objective was to evaluate physiological changes (glucose, lactate, and metabolic rate) associated with hypoxia at 2 temperatures, and determine whether these variables could predict subsequent performance of crab. Groups of crabs were exposed to 8°C and –15°C for 45 minutes and hemolymph was collected at various intervals post-treatment. Glucose and lactate concentrations were determined with spectrophotometric techniques. Exposure to subfreezing temperature led to higher lactate concentrations. Higher glucose concentrations were associated with higher mortality. New groups of crabs were exposed to both temperatures for 15, 30, or 45 minutes and the metabolic rate was monitored immediately and after 12 hrs using closed respirometry chambers. Severe temperature and duration of stressor led to lower metabolic rates. Lower metabolic rates were associated with higher mortality.

J. Mondragon: Distribution and movement of king and Tanner crab in Glacier Bay

Tanner and king crabs were systematically sampled throughout Glacier Bay. Tanner crabs were widely distributed except in the lower mouth of the bay where no crabs were caught. Large males (>80mm) overlapped in their distribution with adult old-shell females and high catch of adult females was predictive of a high catch of large males. Immature crabs were shallower and concentrated in a few hotspots. Red king crabs were mainly found in one small area of the East Arm. Male and female king crabs co-occur. The acoustic tagging program was described, where the objectives include evaluating the efficacy of the closure (reserve) boundaries. Preliminary results indicate that some male Tanner crabs move large distances. King crab movements appear to be coordinated, as if they are moving in a herd.

J. Nielsen, J. Taggart, J. Mondragon, and A. Andrews: Distribution of juvenile Tanner crabs: nursery areas in Glacier Bay?

Almost half (44%) of the juveniles caught in a comprehensive systematic survey of Glacier Bay occurred in 2 areas, both narrow glacial fjords, whereas adults were found to be more widespread. These high density juvenile areas tend to be colder and had fewer adults than other areas where juveniles occur; all juveniles generally occurred at depths less than 150 m. The hypothesis proposed is that narrow glacial fjords serve as nursery areas. If this hypothesis is correct, these juvenile populations could feed into adult concentrations that support the commercial fishery near other glacial fjord areas of southeast Alaska.

A. Baldwin: Deep sea corals as habitat for chirostylid crabs and other invertebrates on seamounts in the Gulf of Alaska

This study was based on transcription of videos from the submersible Alvin dives on Gulf of Alaska seamounts, and is part of the Gulf of Alaska Seamount Exploration (GOASEX) project. Chirostylid crabs were commonly associated with corals and seemed to prefer some types of corals over others. Coral types avoided were mostly shorter corals. Crabs seemed to exclude basket stars except on very large *Paragorgia* (bubble gum) corals, where they co-occurred. Most crabs were solitary on individual corals.

Special Topic: Overfishing and Biological Reference Points

J. Zheng: Estimating M for crab stocks: methods, examples, challenges and hope

The importance of estimating M for use in population models and harvest strategies was emphasized, while acknowledging that M is one of the least understood parameters. Advantages and limitations of 5 estimation methods were reviewed: life history analysis (e.g., Hoenig's 1983 regression and the 5% rule), catch-curve analysis, ratio method, mark–recapture experiments, and population models. Variability in estimates was exemplified for Bristol Bay red king crab; for other king, as well as Tanner and snow crabs in Alaska; and for various other commercial crabs species worldwide. Challenges were categorized as due to 1) difficulties in ageing, 2) inappropriateness of transferring life history relationships from fish to crabs, 3) problems with tagging including negative effects on growth and survival, 4) confounding of parameters in length-based models is exacerbated as compared to age-based methods, and 5) variation in M with size, maturity, shell condition, and time. These difficulties were put into perspective in a review of estimates of M for groundfish as made by the several prominent NOAA regional Fisheries Science Centers and by ICES. When looked at as a whole, some general observations are that M=0.2 is a common standard for many groundfish stocks, Hoenig's (1983) formula is at least as popular as the 5% rule, and assessment models are often used to refine M estimates when good data are available. For crab stocks where information is lacking and there are no similar stocks from which to borrow estimates of M, the recommendation is to use a 1% rule (M=-ln(0.01)/tmax). This is a common and conservative approach with a result almost the same as Hoenig's formula, but does not

run the risk of being as overly conservative as the 5% rule. Where good data are available, the recommendation is to use simple population models (e.g., catch curve analysis with q=1) to estimate M and reduce parameter confounding.

G. Thompson: A history of the concept of "overfishing" as interpreted in the National Standard Guidelines

This was an insider's report of the history of the development of overfishing definitions from 1977 to the present. The intent of the guidelines was to avoid irreversible damage to the capacity of a stock to recover to the maximum sustainable yield (MSY) producing level, i.e., to prevent recruitment overfishing. The first guidelines were drafted in 1977 with revisions published in 1983, 1989, and 1998. Currently, each fisheries management plan (FMP) is required to include a specific overfishing definition designed to be measurable. Overfishing refers to the rate of fishing (F) whereas overfished refers to stock size; however, these concepts were made synonymous (and muddled) in the Sustainable Fisheries Act (1996). That act also defined optimum yield (OY) as ≤ MSY. National Standard Guidelines (NSGs) published in 1998 separated overfishing and overfished, such that a stock is overfished if it is not expected to rebuild to B_{MSY} within 10 years when fished at the maximum fishing mortality threshold (MFMT). The lower limit of the minimum stock size threshold (MSST) is set at ½ B_{MSY}. As of April, 2002, the draft Compliance Report indicated that only 35% of MFMT specifications comply with NSGs, and only 6% of MSST specifications comply with NSGs *(copies of Dr. Thompson's Powerpoint presentation are available from Peter van Tamelen at ADF&G, Juneau*).

G. Thompson: Report of the NMFS National Standard 1 Guidelines Working Group

This presentation was a summary of work that began in May 2003 towards revising NSG 1 (overfishing definition). The "big picture" purpose is to revise the guidelines to clarify, simplify, amplify, but a major overhaul is not required. The desire is to strengthen the requirements for ending overfishing, while increasing the flexibility for rebuilding periods (not to justify continued overfishing). Approved rebuilding plans may be grandfathered in. Ten issues were identified for review and recommendations were made for each. The 10 issues are: 1) stocks, fisheries, and assemblages; 2)fishing mortality thresholds; 3) stock size thresholds; 4) rebuilding time horizons; 5) rebuilding targets; 6) revision of rebuilding plans; 7) OY control rules; 8) terminology (threshold vs. limit and overfished vs. depleted; 9) technical issues; and 10) international fisheries. One example of the recommendations is that for OY: each FMP must have an OY target control rule, such that OY is achieved on average, and where the OY control rule is less than MSY rule throughout their ranges.

J. Turnock: Draft work plan for the Crab Plan Team FMP work group

This presentation summarized the draft work plan of the crab plan team work group charged with recommending revisions to the Bering Sea/Aleutian Islands crab Fishery Management Plan (FMP). The focus is on clarifying the overfishing definition and 10

additional technical items: 1) SY, 2) M, 3) Z_{MSY}, 4) overfished determination, 5) conservation equivalency, 6) buffer between MFMT and target F, 7) tier system, 8) limit reference point system, 9) projection modeling, and 10) sensitivity analysis. This work is interim, and will be presented to the Scientific and Statistical Committee (SSC) of the North Pacific Fishery Management Council as progress is made. The first presentation is scheduled for the February 2004 meeting.

G. Thompson: Harvest control rules: the "tier system" for groundfish

This presentation was a brief overview of the 6 tier system in place for groundfish under FMPs in Alaska. Tiers can be classed according to the graphical shape of the harvest control rule (HCR). HCRs in Tiers 1–3 have similar shapes, where F is constant if biomass is above the reference level, F varies with B below the reference level, and F=0 if biomass is extremely low. HCRs in Tiers 4–5 have constant F regardless of biomass. HCRs in Tier 6 are unique with constant catch regardless of biomass (unless the SSC has a better idea).

Alternatively, tiers can be classed according to the amount of information available, with less information available for higher tier number:

- Tiers 1–2 are based on MSY directly
  - Tier 1: use when uncertainty *can* be estimated
  - Tier 2: use when uncertainty *can't* be estimated
- Tiers 3–4 are based on spawning per recruit
  - Tier 3: use when recruitment *can* be estimated
  - Tier 4: use when recruitment *can't* be estimated
- Tier 5 are based on the natural mortality rate
- Tier 6 are based on average catch

PLANS FOR 2004

The annual Alaskan crab research meetings have continued to be productive and valuable for free exchange of scientific results, ideas, and perspectives. An 11th annual meeting is expected to be scheduled for the approximate dates of 15–17 December, 2004 in Anchorage.

The proposal for next year's special topic is larval dynamics. This focus on larval dynamics would include feeding, growth, movements, and predation, with some focus on stock–recruitment relationships. Ginny Eckert and Peter van Tamelen will outline major topics and develop a list of potential invited speakers.

Proposals for other special topics are welcome. Please submit these to Rich Marasco and/or Doug Woodby.

Appendix 1. List of participants at the 2003 interagency crab research meeting.

Last Name	First Name	Affliation	Location	Email
Alinsunurin	Rachel	ADF&G	Dutch Harbor	Rachel_alinsunurin@fishgame.state.ak.us
Baldwin	Aaron	UAF	Juneau	ftapb1@uaf.edu
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Berceli	Robert	ADF&G	Cordova	Robert_berceli@fishgame.state.ak.us
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Bornhold	Beth	DFO	Prince Rupert	BornholdE@PAC.DFO–MPO.GC.CA
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Marasco	Rich	NMFS	Seattle	Rich.Marasco@noaa.gov
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Nielsen	Julie	USGS	Juneau	ftjkn@uaf.edu
Park	Won	UAF	Juneau	ftwp1@uaf.edu
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Salmon	Melissa	ADF&G	Dutch Harbor	melissa_salmon@fishgame.state.ak.us
Savikko	Herman	ADF&G	Juneau	herman_savikko@fishgame.state.ak.us
Schwenzfeier	Mary	ADF&G	Dutch Harbor	mary_schwenzfeier@fishgame.state.ak.us
Shepard	Ric	ADF&G	Kodiak	ric_shepard@fishgame.state.ak.us
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Last Name	First Name	Affliation	Location	Email
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Urban	Dan	ADF&G	Kodiak	dan_urban@fishgame.state.ak.us
van Tamelen	Peter	ADF&G	Juneau	peter_vantamelen@fishgame.state.ak.us
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Webb	Joel	UAF	Juneau	ftjbw1@uaf.edu
Woodby	Doug	ADF&G	Juneau	doug_woodby@adfg.state.ak.us
Zheng	Jie	ADF&G	Juneau	jie_zheng@fishgame.state.ak.us

Appendix 2. Final agenda for the 2003 interagency crab research meeting.

INTERAGENCY CRAB RESEARCH MEETING
December 16-18, 2003

The Hotel Captain Cook
4th and K Streets
Anchorage, AK
907-276-6000

TUESDAY, DECEMBER 16: RESEARCH REVIEW (Endeavor Room)

Afternoon Session: 1:00 – 4:30 pm

I. Introductions

II. Opening remarks: Rich Marasco, Doug Woodby

III. Meeting agenda: Modify and Adopt

IV. Highlights of ongoing and planned crab research (All presentations will be 15 - 20 minutes)

A. NMFS

1. RACE Kodiak 2002 activities – Bob Otto (Cancelled)
2. Crab disease research – Frank Morado (Cancelled)
3. Crab disease research II – Pam Jensen
4. Comparison of Primiparous and Multiparous Tanner Crab Egg Development – Kathy Swiney
5. Dungeness Crab Size at Maturity on the East Side of Kodiak – Kathy Swiney

Coffee: 2:45-3:15

B. ADF&G – Southeast and Central Regions

1. A laboratory study of tag retention and survival of PIT tagged Tanner crab – Gretchen Bishop
2. Preliminary findings of 1999 - 2003 Southeast Alaska Dungeness crab survey work – Jan Rumble
3. Central Region (CF) – Bill Bechtol
4. Electronic Data Capture for Crab Surveys – Peter van Tamelen, Headquarters

C. DFO - Canada

1. Overview of the crab fishery and related research in BC – Beth Bornhold

WEDNESDAY, DECEMBER 17: RESEARCH REVIEW (Endeavor Room)

7:45 - 8:15 am Coffee

Morning Session: 8:15 am - 11:45 am

ADF&G – Westward Region

1. Update on Crab Observer Database – Ryan Burt

1. Crab Observer coral bycatch recording project – Mary Schwenzfeier
2. BS-AI king crab pot surveys – Leslie Watson
3. Bering Sea Crab Test Fish Project – Skip Gish
4. Dungeness and Tanner male size-at-maturity – Dan Urban
5. Update on King Crab Field Manual – Susie Byersdorfer

Coffee: 9:45-10:15

B. ADF&G – Anchorage and Headquarters
   1. Update of molecular genetics studies of red king crab and hybrid Tanner and snow crabs – Lisa Seeb (Cancelled)
   2. Using thermal modeling to reduce handling mortality in snow crabs – Peter van Tamelen

C. Universities
   1. Energetics of snow crabs – Tom Shirley, UAF, Juneau
   2. Lipofuscin aging of snow crab - Bodil Bluhm and Tom Shirley, UAF, Juneau
   3. Vertical migration and seasonal timing of four sympatric *Cancer* spp. larvae in southeastern Alaska – Won Park, UAF, Juneau
   4. Patterns of morphological plasticity, energy content, and weight due to varying incubation temperature of snow crab zoeae – Joel Webb, UAF, Juneau

Lunch: 11:45-1:15

Afternoon Session: 1:15 – 4:30 pm

5. Molting biology of snow crabs – Sherry Tamone, UAS, Juneau
6. Reproductive hormones in *Chionoecetes opilio*?: effect of temperature on reproductive biology – Jaqueline Mitchell, UAF, Juneau
7. Does appendage loss result in increased mortality for Dungeness crabs? – Tom Shirley, UAF, Juneau
8. MADS (Multi Agency Dungeness Study) update: 4 years post closure – Jim Taggart, USGS
9. Physiological responses of Tanner crabs (*Chionoecetes bairdi*) to physical stressors associated with Alaskan crab fisheries – Sonya Elmejjati, UAF, Fairbanks

Coffee 2:30-3:00

1. Distribution of Tanner and red king crab in Glacier Bay & preliminary tagging results – Jennifer Mondragon, USGS
2. Distribution of juvenile Tanner crabs: nursery areas in Glacier Bay? – Julie Neilsen, UAF, Juneau
3. Spatial patterns in snow crab: implications for assessment and management strategies – Andre Punt, UW (Cancelled)
4. Deep Sea corals as habitat for chirosylid crabs and other invertebrates on seamounts in the Gulf of Alaska – Aaron Baldwin, Tom Shirley, and Brad Stevens, UAF, Juneau

B. Revised Research Plan – Doug Woodby

C. Next Year's Meeting and Special Topic Suggestions

Crabby Hour and Dinner at the Snow Goose: 6:00-10:00

THURSDAY, DECEMBER 18: OVERFISHING AND BIOLOGICAL REFERENCE POINTS II (Endeavor Room)

7:45 - 8:15 am Coffee

Morning Session: 8:15 am - 12:00 noon

I. Workshop on Overfishing Definitions and Biological Reference Points II

A. Introduction – Rich Marasco, NMFS

B. Estimating natural mortality for crab stocks: approaches, examples, challenges, and hope – Jie Zheng, ADF&G, Headquarters (30 minutes)

C. NMFS national standards, guidelines, and overfishing definitions – Grant Thompson, NMFS (60 minutes)

Coffee: 9:45-10:00

D. Work Plan of the Bering Sea and Aleutian Island Crab Overfishing Definition Working Group – Working Group Members (60 minutes)

E. Definitions, Biological Reference Points, and Harvest Strategies – General discussion

II. Other business